Compensation of the Elliptical Polarization Undulator (EPU)

Greg Portmann[1] and Christoph Steier[2]

[1]Engineering, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA
[2]Accelerator and Fusion Research, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA

The first Elliptical Polarization Undulator (EPU) to be installed in the ALS has been commissioned during the last year. This undulator has a period of 5 cm and a length of 1.85 m and is used mainly for magnetic spectroscopy experiments in a photon energy range from below 100 eV up to 1.5 keV. It was designed to provide four polarization modes: circular, elliptical, linear horizontal and vertical. In addition first tests were carried out to provide linear polarization with arbitrary orientation (between vertical and horizontal). Similar to all the other undulators the users of the EPU are allowed to change the gap of the EPU to produce photons of different energies. The difference between the EPU and all other undulators is that the users are allowed to shift the two opposing halves (one half of the upper and one half of the lower poles) longitudinally. Changing the geometry and therefore the field strength and field configuration of the magnetic field of the device also changes the (residual) field integrals. This has a direct influence on the electron beam both in orbit and in beam size. The main focus so far was put on orbit stability (like for all other insertion devices). To correct the orbit a feed forward algorithm was developed using a two dimensional table.

A significant difference of the EPU as compared to the other ALS undulators arises from the speed at which the users of the EPU change the polarization direction. In other devices the gap motions are slow. In the EPU the gap motions are much faster (movement speed of up to 16 mm/s corresponding to a change from left to right circular polarization in about 1.5 s). In addition a change in polarization direction changes the field integrals of the EPU by about the same amount as changing the gap from fully open to fully closed (~200mm). Therefore the current orbit feed forward (correction) system which is similar to the ones at the other undulators turned out to be too slow to keep the orbit values down to reasonable values (<3 microns).

During user operation the longitudinal gap motion was initially limited to 1mm/s. At this speed the time to shift from left to right polarization is 25 s. Several improvements in the feedforward control algorithm in the past year have permitted us to increase the speed limit to 3 mm/s (8 seconds to shift from left to right polarization). This is at the limit of the present control system. In order to increase the speed further a new local feed forward system with about 100 Hz bandwidth was designed and is currently being implemented. In addition the effect of eddy currents was measured and turned out to be small. Therefore the new system should allow to keep the closed orbit changes even at full speed within reasonable limits.

A second problem for the orbit stability when changing the EPU gap or shift parameter arises from the fact that the local chicane magnets, which allow two independent undulators feeding independent beamlines into one straight, show a significant hysteresis. Therefore they are not suited to be used in a feed forward system. Instead two horizontal and two vertical correctors (the normal correctors in the arcs show significantly less hysteresis) at the beginning of the arcs upstream and downstream from the EPU are used to correct orbit errors. Because the EPU is situated asymmetrically in one half of the straight this corrector arrangement cannot cancel the orbit distortion within the EPU straight completely (even so the distortion outside that straight is very small). This distortion can be more than 20 microns in the vertical plane. Measurements have been conducted together with the experimenters on Beamline 4.0.1-2 to determine how serious the impact is. First results indicate that for the experiments conducted at the moment, the impact is negligible.

To solve the problem the design of new chicane magnets has been started. On a shorter time scale a solution has been tested to use four instead of two correctors in each plane reducing the orbit error at the EPU by a factor 2-3.

So far most of the efforts on the insertion devices went into compensating orbit distortions. Unfortunately all undulators also influence the betatron tunes, chromaticity and emittance coupling. In the last year this has been studied more extensively than before and some immediate remedies have been implemented to reduce the impact on beam quality. The problem turned out to be most serious for the EPU, which has several reasons. First the EPU frequently changes its longitudinal shift parameter to change the polarization. This causes a distortion in the field integrals of about the size as changing another undulator from fully open to fully close (which occurs very seldom during user operation). In addition the horizontal beta function in the insertion device straights is about 3 times as large as the vertical one. Therefore the horizontal tune shift from the EPU which occurrs when changing the shift parameter is very significant (see Fig. 3). Finally the possible speed of shift parameter changes is much faster which makes slow corrections using the lattice quadrupoles virtually impossible.

Since the vertical beamsize at the ALS is artificially increased using skew quadrupoles to increase the lifetime, a change in betatron tune immediately results in a change in beam size. Therefore these tune changes are impacting user operation.

To cure the problem several ideas have been developed and some of them tested on the ALS. Some are trying to generate vertical emittance independent of coupling. Unfortunately no solution that did not compromise some other beam quality item has been found so far. A completely different approach could be the lattice with lower vertical beta function. This lattice provides a lifetime comparable or better than the current lattice with skew quadrupoles without using any artificial coupling. First tests were carried out and showed that a change of the EPU shift parameter in that case does not change the beam size at all.

Independent of those efforts to make the operation of the EPU more transparent to the electron beam a new operation mode has been tested. In this mode the two moveable halves are shifted parallel instead of anti parallel. This provides linear polarization of arbitrary orientation (in contrast to the fixed horizontal and vertical linear, elliptical and circular polarization one gets in the normal mode). The influence on the beam was about the same as in the normal operation mode and feed forward correction of the orbit distortion will be eased by the fact that the resulting orbit error is mostly horizontal.

This work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Materials Science Division, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

Contact person: Greg Portmann, Engineering, Ernest Orlando Lawrence Berkeley National Laboratory. Email: GJPortmann@lbl.gov. Telephone: (510) 486-5924.

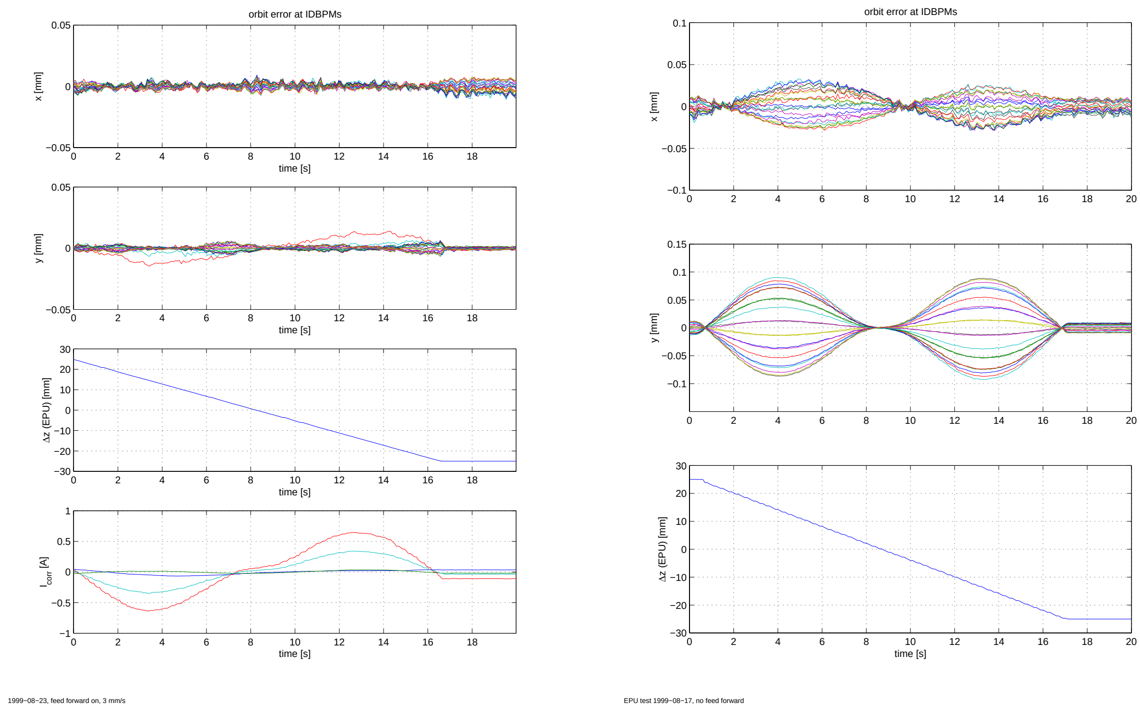

Figure 1. Orbit error resulting from a change of the shift parameter of the EPU with (left) and without (right) the feed forward system active.

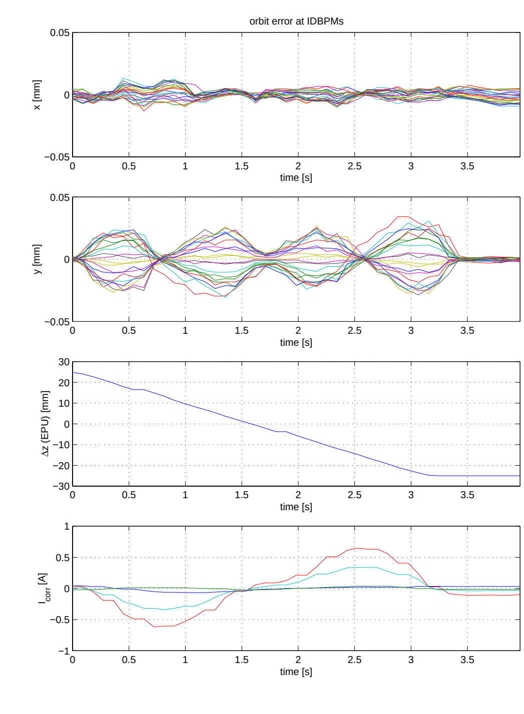

Figure 2. Orbit distortion with current feed forward system at maximum velocity.

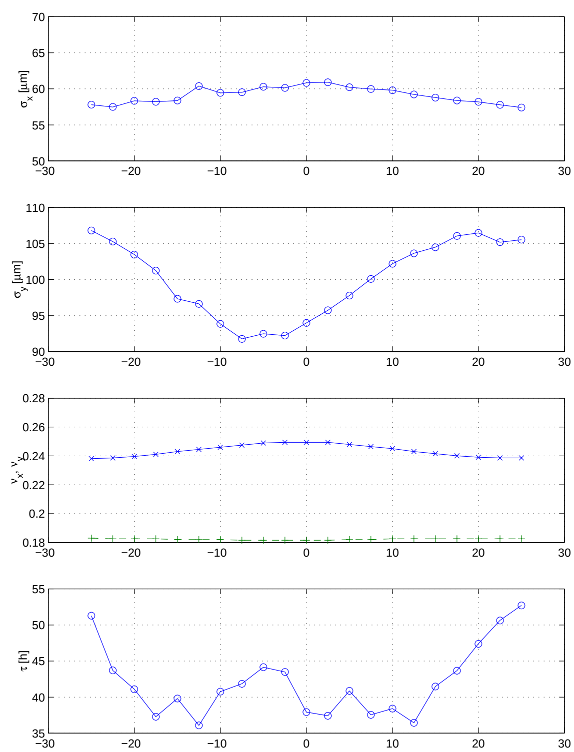

Figure 3. Betatron tune, beam size and lifetime variation resulting from changing the EPU shift parameter.